Signals and Circuits

ENGR 35500

Nodal Analysis

Chapter 3: 3-1 (Node-voltage method) pp. 95-100

Ulaby, Fawwaz T., and Maharbiz, Michael M., *Circuits*, 2nd Edition, National Technology and Science Press, 2013.

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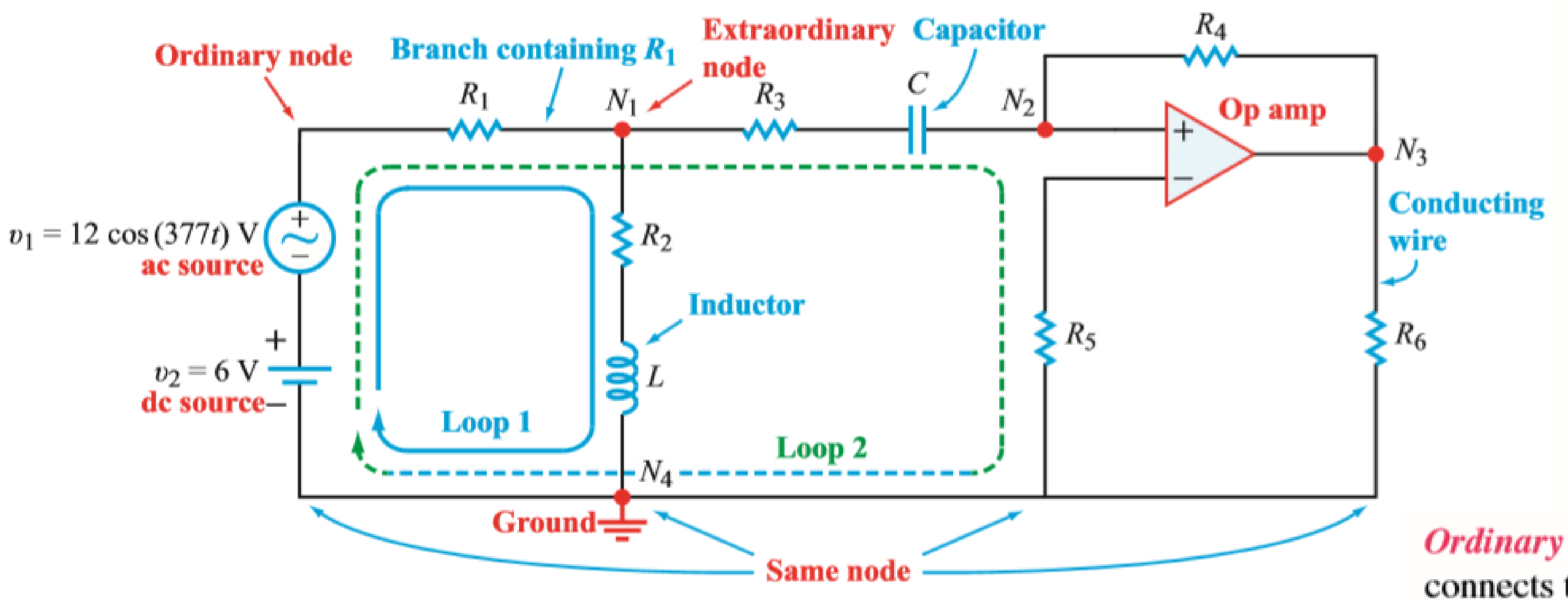
Nodal Analysis

- Sometimes also called node-voltage analysis;
- Based on KCL;
- Based on distinguishing types of nodes.

Circuit Architecture



Ordinary node: An electrical connection point that connects to only two elements.

Extraordinary node: An electrical connection point that connects to three or more elements.

Branch: Trace between two consecutive nodes with only one element between them.

Path: Continuous sequence of branches with no node encountered more than once.

Extraordinary path: Path between two adjacent extraordinary nodes.

Loop: Closed path with the same start and end node.

Independent loop: Loop containing one or more branches not contained in any other independent loop.

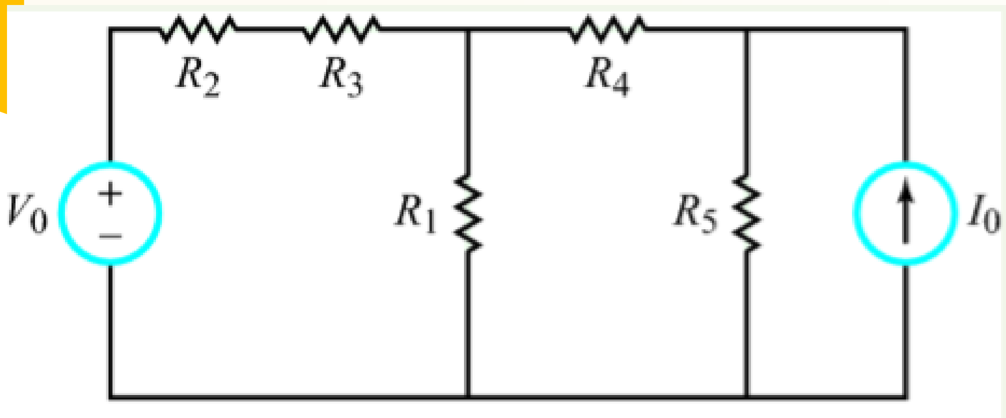
Mesh: Loop that encloses no other loops.

In-series: Elements that share the same current.

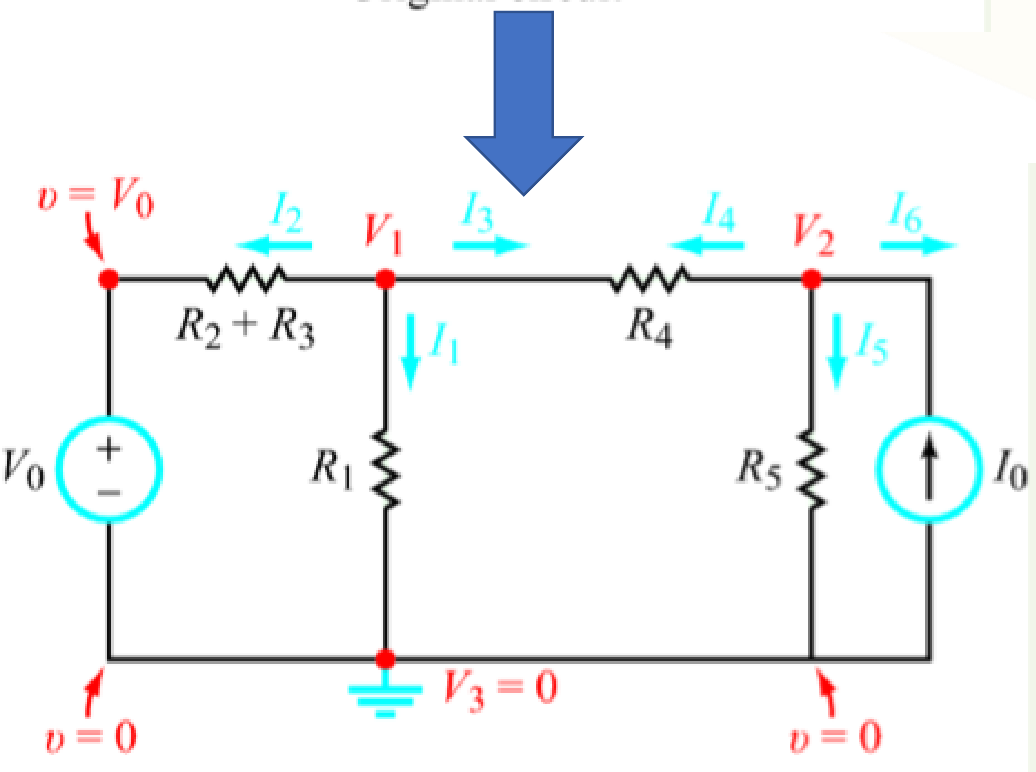
In-parallel: Elements that share the same voltage.

Nodal Analysis

Given $V_0 = 10V, I_0 = 0.8\ A, R_1 = 5\ \boldsymbol{\Omega}, R_2 = 2\boldsymbol{\Omega}, R_3 = 3\boldsymbol{\Omega}, R_4 = 10\boldsymbol{\Omega}, R_5 = 2.5\boldsymbol{\Omega}$, ***caculate the power consumed by*** R_5.



Original circuit



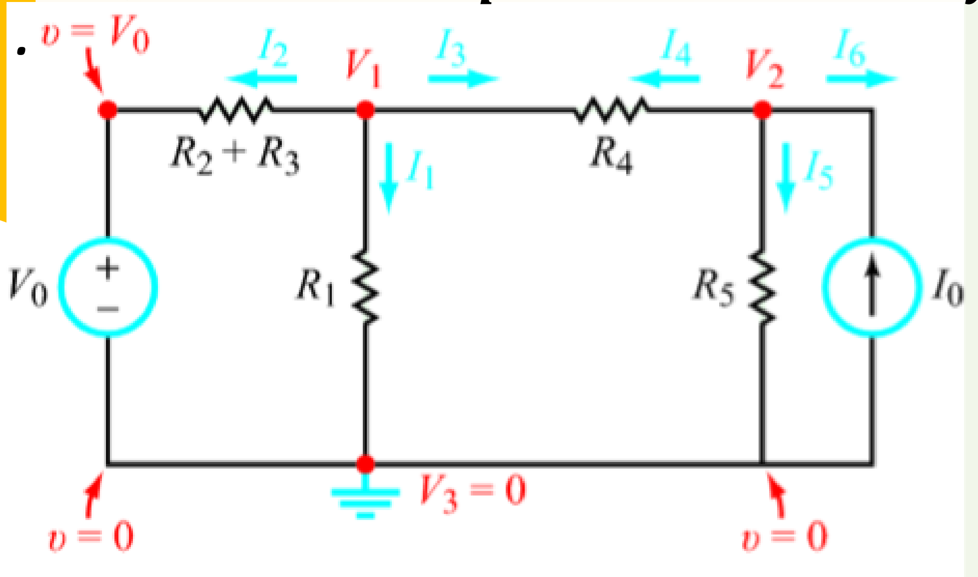
Circuit with designated node voltages

Step 1: Identify all extraordinary nodes, select one of them as a reference node (ground), and then assign node voltages to the remaining (n_{ex} - 1) extraordinary nodes.

Step 2: Label the currents around the (n_{ex} - 1) extraordinary nodes. Usually we label them as leaving nodes.

Nodal Analysis

Given $V_0 = 10V, I_0 = 0.8\ A, R_1 = 5\ \boldsymbol{\Omega}, R_2 = 2\boldsymbol{\Omega}, R_3 = 3\boldsymbol{\Omega}, R_4 = 10\boldsymbol{\Omega}, R_5 = 2.5\boldsymbol{\Omega}$, ***caculate the power consumed by*** R_5.



Circuit with designated node voltages

Node 1:

$$I_1 + I_2 + I_3 = 0 \qquad (1)$$

$$\frac{V_1 - 0}{R_1} + \frac{V_1 - V_0}{R_2 + R_3} + \frac{V_1 - V_2}{R_4} = 0 \qquad (2)$$

Node 2:

$$I_4 + I_5 + I_6 = 0 \qquad (3)$$

$$\frac{V_2 - V_1}{R_4} + \frac{V_2 - 0}{R_5} - I_0 = 0 \qquad (4)$$

Step 1: Identify all extraordinary nodes, select one of them as a reference node (ground), and then assign node voltages to the remaining (*n**ex* - 1) extraordinary nodes.

Step 2: Label the currents around the (n_{ex} - 1) extraordinary nodes. Usually we label them as leaving nodes.

Step 3: At each of the (n_{ex} - 1) extraordinary nodes, apply the form of KCL requiring the sum of all the currents leaving a node to be zero.

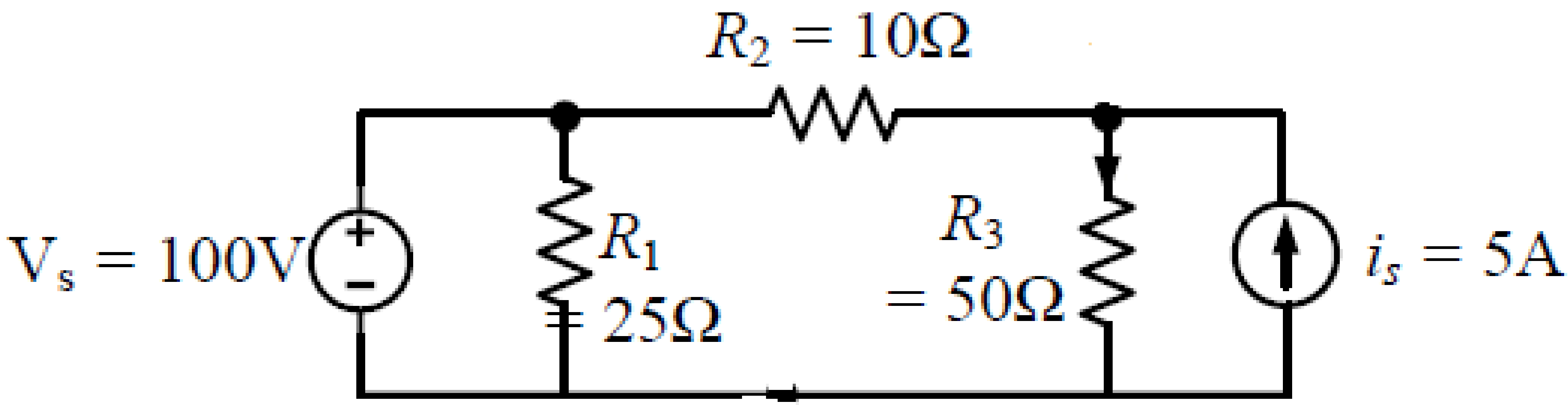
Step 4: Try to express the currents at each of the (n_{ex} - 1) extraordinary in terms of voltages and known parameters, especially using Ohm's law.

Step 5: Solve the independent simultaneous equations to determine the unknown node voltages.

Nodal Analysis

Practice

Calculate the power consumed by R_3.



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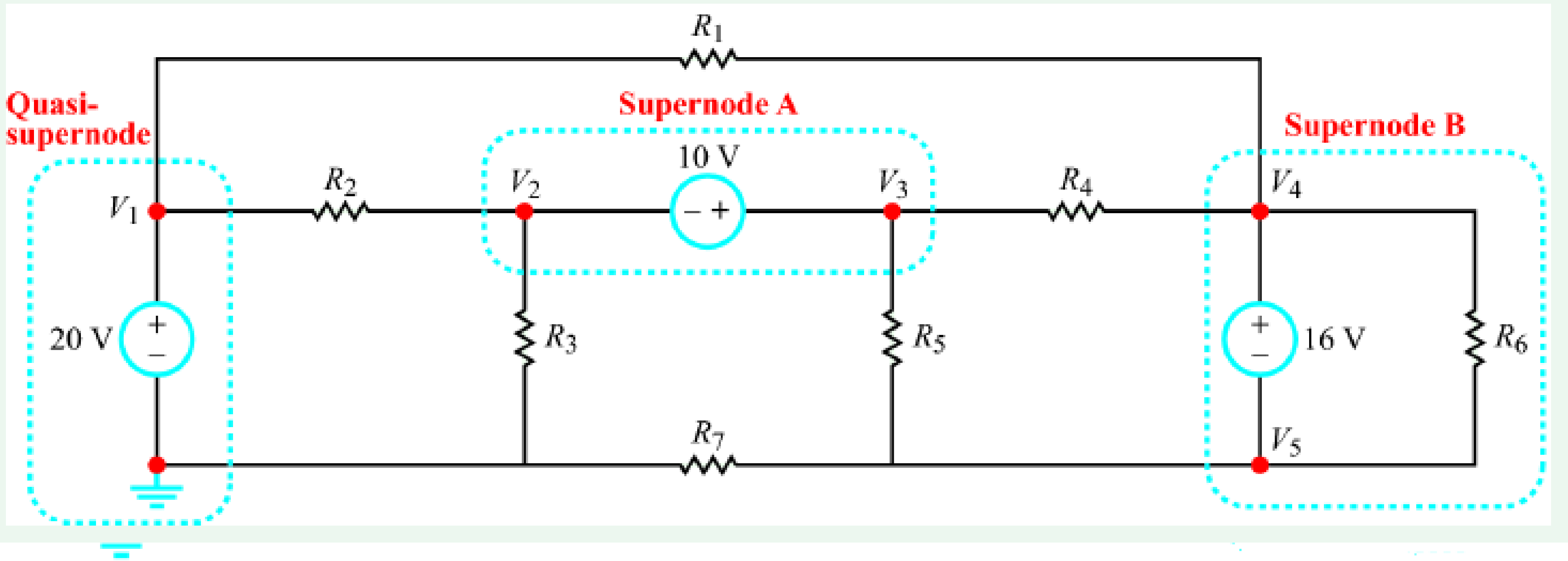
Nodal Analysis

Supernodes

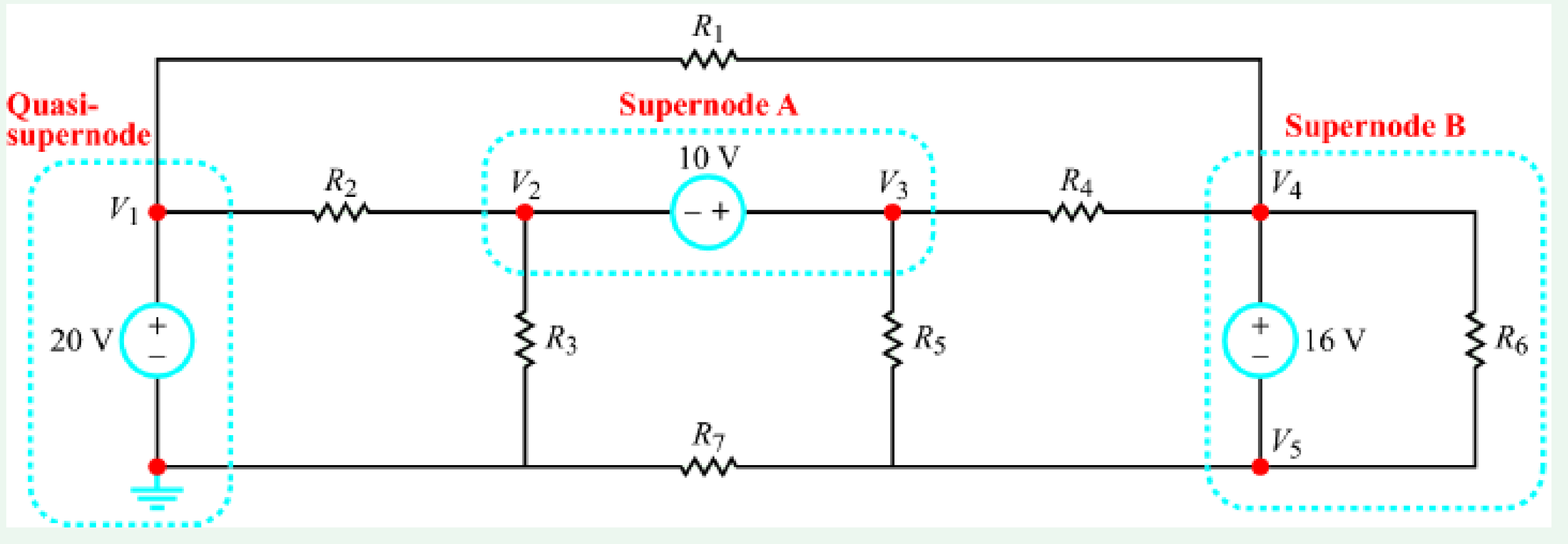


A ***supernode*** is the combination of two extraordinary nodes (excluding the reference node) between which **voltage source** exists. The voltage source may be independent or dependent type, and the voltage source may include elements in parallel with it, but not in series with it.

It one of the two nodes of a supernode is a reference (ground) node, it is called ***quasi-supernode***.

Nodal Analysis

Supernodes



At a super node, KCL can be applied to the combination of the two nodes as if they are single node.

At a super node, KVL can be used to express the voltage difference between the two nodes in terms of the voltage of the source between them.

Two equations

The resistor in parallel with the voltage source does not have influence on the currents and voltages in other parts of the circuit.

For a quasi-supernode, the node-voltage of the non-reference node is equal to the voltage magnitude of the source.

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Nodal Analysis

Supernodes

Example: Determine the node voltage for the following circuit